

Patent Prospecting: Mapping of Patent Applications Filings for the Fertilizer Product as Green Technology Over the Last Decade

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Abstract

This study aims to carry out patent prospecting for the fertilizer product. The justification for such a proposal lies in the relevance and application of the information that patent documents can provide about an invention. Furthermore, it considers the current scenario of Brazil's dependence on the import of fertilizers, bearing in mind its position in the global agribusiness. To this end, the study develops a refined analysis of patent applications in the DERWENT database with code C05F of the IPC Green Inventory of the World Intellectual Property Organization (WIPO), following a time frame between 1986 and the 2010 and 2023 period. Among the main results, the study shows that the technological information in patent documents can be helpful to Brazil's development of eco-friendly technologies. To corroborate this statement, there are 6,337 inventions with IPC code C05F that have not been filed in the country that can be analysed, studied, and used since they have not been patented in its territory. By pointing out the exponential evolution of patent filing requests with code C05F from WIPO's IPC Green Inventory in the world, the study shows that China is the country with the highest number of patent filing requests with that code, via PCT (n=6,476 requests). On the other hand, the analysis shows that, excluding China, Brazil ranks 5th in the number of patent filings (n=45). However, compared to Russia (n=153) and South Korea (n=143), the number of requests is significantly lower. The study also shows that Brazil has filed significantly fewer patent applications for code C05F in WIPO's IPC Green Inventory per year when compared to other countries, with less than five filings in the period, highlighting the discrepancy between the country's need to consume the fertilizer product and its presence in global agribusiness. In conclusion, this patent prospection highlights the importance of research into environmentally sustainable technologies, especially when it comes to Brazilian agribusiness, as well as demonstrating that there is a lot of technology that can be used in Brazil at zero cost, taking into account the information contained in the patent documents worldwide.

Keywords: fertilizers, technological information, patents, patent prospecting

1. Introduction

Patents are temporary property titles, granted by the State to inventors, authors, or other natural or legal persons holding rights to creation (Instituto Nacional da Propriedade Industrial, 2020).

The details contained in patent documents provide valuable insights into technology and legal matters that may not be available in other publications. Patent documents can provide all the information registered and published about an invention or even the information included in the patent files being considered (Cunha, Volpato, & Pedronc, 2023).

The technological information provided by patents is based on information provided by the applicant, even when it is pending approval. That means it is possible to find applications and general technical questions about the invention and to help determine freedom of operation in each territory. In short, patents not only grant the holder the exclusive right to use an invention but also reveal a wealth of information about all types of technological documents (Oliveira et al., 2005; Singh, Chakraborty, & Vincent, 2016).

Due to their characteristics, patents play an important role in developing new technologies through financing, research, and development, as they encourage innovation in small and medium-sized companies, industries, research institutions, and the academic world. Furthermore, they play a fundamental role in the economic development of a country.

Brazil, the fifth largest country in terms of area and population and the largest in terms of arable land, is among the few countries with the potential to increase agricultural productivity. Over the last two decades, Brazil has been consolidating its position as a major producer of agricultural commodities and related food products, as well as a supplier to international markets (Farias et al., 2021). The continued expansion of trade and the diversification of markets and products remain at the heart of Brazil's agricultural growth strategy. However, increases in the costs of fertilizers, an important input for agricultural production, represent a challenge to the long-term growth of Brazilian agriculture (Oliveira, Doner, & Almeida, 2023). At the same time as Brazil is one of the world's largest leaders in agribusiness, it is also one of the largest importers of fertilizers, highlighting the need for more research and innovation in technology.

Given these considerations, the question arises: What is the relevance of mapping patent application filings on the fertilizer product given the technology and information contained in these documents?

Therefore, the study has the general objective of carrying out patent prospecting for the fertilizer product to demonstrate the importance of the technological information in the patent documents. Regarding specific objectives, this study aims to present a refined analysis of patent applications in the DERWENT database, regarding patent applications with code C05F of the IPC Green Inventory of the World Intellectual Property Organization (WIPO), as well as identify patent applications that were not filed in Brazil and which can be exploited by the national industry in the production of fertilizers. To this end, through a review of relevant literature, this study conceptualizes patents and contextualizes their relevance as a source of technical and specialized information. Next, the study explores the advantages and peculiarities of searching patent databases to investigate prior art relevant to a potentially patentable invention. Furthermore, the study focuses on the fertilizer product, the object of the research, to develop the proposed patent prospecting.

2. Literature Review

2.1 Concept and Importance of Patents for Sustainability

According to the World Intellectual Property Organization (WIPO), a patent is an exclusive right provided by the State to inventors for their products or processes that offer a new technical solution to an existing problem or provide a new way of doing something. In fact, patents were one of the first types of intellectual property to be recognized in modern legal systems. When an invention is patented, the patent holder is granted exclusive rights to the invention, which allows them to prevent any unauthorized person from using, making, or selling it. In exchange for the patent, the holder must publicly disclose all technical details in the patent documents. The patent typically has a restricted duration of validity, which is usually 20 years. After the patent protection period ends, the information can be used by anyone (World Intellectual Property Organization – WIPO, 2023).

The patent system is designed to benefit all individuals in practice. The possibility of maximizing profits related to patented products or processes during the patent protection validity period allows companies and inventors to be rewarded for their efforts in research, development, and technology, encouraging innovation, which benefits society as a whole. Furthermore, disclosing inventions and patent documents adds to the body of public knowledge, allowing more research and inventions to be produced and shared (Tidwell & Liotta, 2012; Wipo, 2015).

Patents are considered key elements for measuring the advancement of technologies in countries and, more importantly, their impact on development. This is because they both allow the obtaining of monetary benefits through the commercialization, sale, or licensing of technology and are a reflection of the dynamism of knowledge production and technological advances which, in turn, have a positive impact on governments and societies (Trappey et al., 2023). Inventive activity monitoring occurs through the availability and ease of access to information about patents, specifically through the periodic updating of databases by Intellectual Property Offices worldwide. The analysis of patent statistics helps to understand not only the country's growth regarding registration requests and concessions but also technological trends, prioritized or interest markets, and pioneering entities in the area. Among the various reports around the world that collect or include patent data, mention can be made of the Global Competitiveness Report, the Global Innovation Index, and the Annual Review of the Patent Cooperation Treaty, for example, to present them annually to assess the competitiveness and innovation of countries (Wipo & Cornell, 2018).

When it comes to the value of patents in favour of sustainability, Gomes et al. (2023), in research aimed at analysing the panorama of sustainable technologies and patents in the international and national scenario, carried out in databases such as Orbit (a system for searching, selecting, reviewing and exporting information contained in patents) and Patentscope (from WIPO, which allows you to consult 95 million patent documents, including 4.0 million published international patent applications (PCT), with worldwide coverage, as well as the database of the National Institute of Industrial Property (INPI), with national coverage, observed the predominance of environmental protection concepts. Among the sustainable technologies, research to develop technologies for water decontamination, energy conservation, air pollution, and natural materials stands out. This scenario highlights the environmental concern, whether in its pollution, raw materials and their forms of protection. In turn, among the most dominant technologies in research, the areas of food chemistry, environmental technologies, and metallurgical materials reinforce the great trend in concern with technologies aimed at the food industry, as well as the issues of agro technologies and environmental technologies, in general.

Likewise, Silva and Silva-Mann (2022), when seeking to monitor technologies associated with the agricultural sector based on the analysis of information from patent documents at a global level, highlight that research into agricultural systems, soil preparation, fertilization, identification of patterns and inference methods represent not only the main research groups in development and innovation but are also related to the countries that filed the most patents in this sector, such as China, Russia, and the United States. Planting, data processing, and analysis of soil properties are the technological sectors that most seek development among the most recurring patents.

In short, environmental concerns drive sustainable innovations, and their patents ensure protection. Hence, the prevalence of scientific biodiversity research is aimed at development that involves high technology and added value (Carrara & Russo, 2017).

2.2 Importance of Information Contained in Patent Documents

In this scenario, patent documents represent a relevant source of technical, legal, and commercial information. In turn, they are an important resource for researchers and inventors, entrepreneurs, industries, commercial companies, and professionals in the area of intellectual property when it comes to discovering what already exists about each search object and develop solutions from each specific point; monitor competitors and meet and locate potential partners; to use the information to identify patents that are no longer in force and that can be used freely; to identify trends in technology or the market at an early stage and ultimately to avoid infringing the patent rights of other people, companies or institutions (Singh, Chakraborty, & Vincent, 2016). In promoting the dissemination of new concepts and inventions, patents also provide security for creativity, since inventors can commercialize their creations without worrying about competition from others, obtaining a profit from their discoveries in addition to being able to sell or license their inventions to third parties (Ma & Porter, 2015).

The use of information in patent documents provides specialized knowledge not found in scientific journals or conference proceedings (Quoniam, Kniess, & Mazieri, 2014). In an estimate, around 70% of the information contained in patent documents will not be made available in any other source of information (Instituto Nacional da Propriedade Industrial – INPI, 2022), which reinforces its importance in research into innovation and technology. Such information is generally presented in more detail than in other documents (Reymond & Quoniam, 2018). Furthermore, aspects such as the description of the content of the documents, universality of the bibliographic data made available, timeliness of information, amount of data, coverage of all technological fields, national, international, and electronic accessibility of documents, and the internationality of classifications represent advantages for the use of information contained in patent documents (Oliveira et al., 2005).

Patent documents contain technical and bibliographic information. Technical information focuses on presenting texts and images of unstructured data that describe aspects such as the state of the art, the details of the invention, and the scope of protection in the form of claims (WIPO, 2023). However, bibliographic information is presented through structured data that includes dates, names and addresses of the inventor, the patent holder, and their legal representative, as well as the classification of the patent, identification of the country of origin of the document, and title of the invention (WIPO, 2023). The data made available is uniform in semantics and format, which allows the tools available in patent bases to be used for metric analyses (Liu, Liao, & Hu, 2011).

In addition to its technical specificities, one of the main points in relation to patent applications is the fact that there is no worldwide patent application. That means that the application must necessarily be made in the country in which patent protection is desired. To this end, the Patent Cooperation Treaty (PCT) emerges as a service based on the WIPO Treaty that allows innovators to seek patents internationally through a single and streamlined procedure. Under the PCT system, it is possible to file a patent application in one language at a patent office within 12 months from the date of the first patent application filed for the same invention, the

so-called priority date. PCT makes it possible to seek patent protection for an invention simultaneously in a large number of countries by filing a single international patent application, rather than filing several separate national or regional patent applications. The granting of patents remains under the control of national or regional patent offices in the so-called national phase. The PCT application has the same legal effect as the filing of separate patent applications in the more than 150 members, known as Contracting States. Furthermore, by using the PCT system, the applicant can defer paying significant national patent-related fees while learning about the likelihood of having a patent granted for the invention, achieving the benefit of having more time and information to help the applicant decide whether, and in which countries, it will seek patent protection (WIPO, 2023a). The application for the Brazilian national phase of PCT occurs with a publication made at WIPO, in the Patentscope® database, and the choice of the National Institute of Industrial Property (INPI) as the International Search and Preliminary Examination Authority in the international phase of PCT (INPI, 2021). Any natural or legal person, or their attorney duly appointed by power of attorney, may apply for a patent for the invention of a new technology for a product or process, as long as it meets the requirements of novelty, inventive step and industrial application (Deng & Lee, 2019; WIPO, 2023). Of these requirements, it should be noted that novelty indicates that the invention must not have been made public, not even by the applicant, before the date of the application; inventive stage means that the product or process must be an inventive solution and industrial applicability implies that it must be possible to effectively manufacture the new invention, which are the criteria for patent applications (Donald, Kabir, & Donald, 2018; INPI, 2021).

Given such peculiarities and advantages, the objective of a patentability search is to find all prior art that may be relevant to a potentially patentable invention. The patent applicant can, based on research, analyse prior art to determine whether it can create a patent application that meets the novelty and non-obviousness requirements characteristic of patents (Oliveira et al., 2005; Cunha, Volpato, & Pedronc, 2023).

Given the importance of patent filings, Favot et al. (2023) state that, in the current global scenario, the creation of green innovations can also contribute to the benefits of a country's technological development. In the context of patents, green patents emerge as valid instruments to boost eco-innovation, understood as the production, assimilation, or exploration of new products and processes, which provide value to customers and businesses, while decreasing and even significantly mitigating the environmental impact compared to known alternatives. The so-called green innovation is measured through three main indicators, namely, research and development expenses (inputs), number of green patents (products), and total productivity of green factors (performance) (Chen & Chen, 2021; Desheng, Jiakui, & Ning, 2021). The patent indicator better reflects the scope of technological innovation a country achieves compared to other indicators (Desheng, Jiakui, & Ning, 2021).

The methods for classifying and identifying patents in green technologies are diverse and are essentially based on four criteria: classification based on codes (International Patent Classification – IPC and Cooperative Patent Classification – CPC, for example); key words; combination of both search techniques; manual selection. Several international organizations, such as the European Patent Office (EPO), the World Intellectual Property Organization (WIPO), and the Organization for Economic Co-operation and Development (OECD), focus many of their studies on the role of patents in the development and dissemination of sustainable technologies, using patent databases (Favot et al., 2023).

2.3 Patent Documents and Fertilizers

As an object proposed by this study, the fertilizer product stands out as an example of the importance of promoting research in technological innovation for the economic development of Brazil. Brazil is a major player in agribusiness but faces challenges in producing fertilizers, which are a crucial part of the input production chain for the sector (Oliveira, Lopes, & Santos, 2020). In fact, despite being the fourth largest country in the agribusiness ranking, Brazil consumes around 8% of global fertilizer consumption, behind only China, India, and the United States. With the accelerated pace of growth in national demand, the country went from exporter to importer of the product, and currently, around 80% of fertilizers consumed in Brazil are of foreign origin. The result is a sector that faces problems such as dependence on international markets, the volatility of exchange rates, and the consequent increase in production and distribution costs, with impacts reaching all stages of the value chain and that are reflected in the economy as a whole (Weid, 2022; Oliveira, Doner, & Almeida, 2023).

Furthermore, the use of fertilizers can contribute to sustainability by increasing soil carbon sequestration, increasing biomass production, and creating a more favourable carbon/nitrogen ratio in the soil, as well as preventing the expansion of the planted area due to increased productivity index and better use of natural resources (Farias, Oliveira, & Santos, 2023).

Fertilizer production in Brazil therefore appears as one of the solutions to the external dependence that the

country faces. Currently, the national policy on fertilizers and inputs for plant nutrition is being drafted, which began in 2022 and should extend until 2050. Between 2010 and 2021, for example, analysis of patents filed in the country shows that the majority of registrations do not refer to products developed for tropical agriculture, with a predominance of foreign filers, suggesting a scenario of perpetuation of technological dependence (Associação Nacional Para Difusão de Adubos, 2020; Brasil, 2021; Farias et al., 2021). It is noteworthy that development research and innovation policies must comply with good practices aligned with the Environmental, Social, and Governance (ESG) concept, as they will be the basis of projects throughout the fertilizer production chain. The objective of this initiative is to enhance the agro environmental performance of agricultural countries while also functioning as a tool for foreign trade and international agreements related to agricultural inputs and products (Associação Nacional Para Difusão de Adubos, 2020). This context tends to favour, in the long term, an increase in the number of projects in interdisciplinary networks involving several organizations of excellence in their specialties. Thus, projects may range from mining to field application for four major chains, namely nitrogen, phosphate, potassium, and, above all, emerging chains (organic and organo-mineral fertilizers; by-products with potential for agricultural use; bio-inputs/biomolecules/bioprocesses for plant nutrition; nanotechnology and new materials, digitalization of agriculture and soil remineralizers) (Associação Nacional Para Difusão de Adubos, 2020; Brasil, 2021; Farias et al., 2021).

In an analysis of patents registered between 2010 and 2021, with applicants from Germany, Brazil, the United States, France, the Netherlands and Norway, for nitrogen fertilizers (considering the CPC/IPC classifications associated with each patent application), for example, it is possible to verify that research takes place more frequently in technological fields focused on fertilizers containing urea, which is precisely the most consumed fertilizer in Brazil, compounds and additives to regulate urease and nitrification in the soil; fertilizers containing ammonium salts or ammonia itself (such as ammonium nitrate) and fertilizer mixtures. Although compositions with urease and nitrification inhibitors are important, among nitrogen fertilizers the relevant presence of organic components prevails. Given this, it is concluded that the main technological search in the sector occurs in terms of increasing the efficiency of fertilizers, such as urease stabilization and nitrification, and release control, among others (Associação Nacional Para Difusão de Adubos, 2020).

The same analysis for phosphate and potassium fertilizers, but taking into account only the Brazilian scenario, shows that the main technological search in the sector is in terms of technologies related to the correlation with nitrogen fertilizers (especially in the use of ammonium phosphate compounds); insertion of organic matrix into the fertilizer composition; additives; presence of micronutrients (such as boron, zinc, copper); innovations relating to fertilizer form (such as fertilizers in liquid form); granulation techniques; coating and/or encapsulation technologies; compositions with modified or controlled release properties; compositions in which sulphur is present (often in elemental form or in the coating); polymer technology; compositions containing microorganisms; presence of fulvic and humic acids; polyphosphates; embedded nanotechnology; micronization; potassium fertilizers from more conventional sources, such as potassium chloride and sulphate; potash fertilizers obtained from volcanic rocks; fertilizers from animal waste; fertilizers from residues from the sugar and alcohol chain; potassium fertilizers produced through thermal processes (Associação Nacional Para Difusão de Adubos, 2020).

This panorama shows that the improvement of a national information and data system enables technical and strategic recommendations to increase efficiency in the use of nutrients in Brazilian mining, industry, and agriculture. Furthermore, strengthening national fertilizer production contributes to the security of domestic supply, provides greater autonomy to the agricultural sector, and boosts the country's economy. To this end, the technological information extracted from patent documents represents a relevant difference, as it allows the exploration of useful informational content to choose the best alternatives and strategies available so that the development, encouragement, and investment in the national production of this important product is possible.

3. Method

3.1 Study Design

This is a patent prospecting study carried out in the Derwent database with code C05F of the WIPO IPC Green Inventory (WIPO, 2023b), created by the IPC Expert Committee, to facilitate the search for patent information related to Environmentally Sound Technologies (ESTs) as listed by the United Nations Framework Convention on Climate Change (UNFCCC). The IPC C05F coding corresponds to bio fertilizers not covered by subclasses C05B and C05C, such as fertilizers originating from waste or rejects (Farias, Oliveira, & Santos, 2023).

3.2 Data Collection

The data for this prospection were collected in the DII database, a patent research tool that combines Derwent

World Patents Index®, Patents Citation Index™, and Chemistry Resource, with references and summaries of thousands of patents with links to cited documents, for citations to patents, related literature and the full texts of documents, in addition to publications from international and national patent registration and granting bodies (Derwent Innovations Index®, 2008).

Advanced keyword searches were carried out in the title and abstract, considering the period from 01/04/2010 to 07/07/2023 as a time range. The analysis was restricted to the period mentioned to detect the most current technologies for the fertilizer product. The patent search in the Derwent database was performed on July 25, 2023. Among the results obtained, patent applications in a secrecy period were not included, which is 18 months from the filing date, as well as the deadline granted for entry into the national phase of each State. At the time, it was possible to identify in prospecting the profile of patent applications relating to the fertilizer product, with code C05F of WIPO's IPC Green Inventory, in Brazil and around the world. Furthermore, the temporal evolution of patent applications in the world and Brazil registered with the IPC code C05F was presented and the current situation of patent application processes in Brazil.

3.3 Data Processing

The data was refined to target only patent filings in the country of origin, excluding those filed via PCT. Subsequently, the refinement considered patent filing requests via PCT, in which a single patent filing request can lead to numerous requests in different countries. It is important to analyse the country of origin of patent application holders to determine where most inventions are being developed.

The collected data were processed in the Microsoft Excel program, from the Microsoft Office® program, data analysis and visualization spreadsheet software.

4. Results and Discussion

The retrieval of patent filing applications in the Derwent database was carried out on July 25, 2023, initially resulting in 18,026 patent documents and subsequently refining the data for applications that only have the WIPO IPC Green Inventory code C05F, when 6,379 initial patent applications were found.

Of the 6,379 initial patent applications with the IPC code C05F, Brazil has 42 filings, 38 of which were filings of patent applications without requiring the PCT and 04 filings with PCT requests that turned into 07 filings. Thus, there are 45 patent applications in Brazil with IPC C05F (Table 1).

Table 1. Requests for patent filings with code C05F of the IPC Green Inventory of WIPO – Derwent

Requests	PCT	
42	45	Brazil
38	38	Patent applications in Brazil alone
4	7	Patent applications with PCT

Source: Prepared by the study authors.

In a second refinement of the total of 6,379 patent filing requests in the world, a total of 5,522 patent filings without the PCT requests were obtained, that is, only in the country where it was filed, resulting in 5,484 patent applications originating from different countries (Table 2).

Table 2. Patent filing requests with WIPO IPC Green Inventory code C05F without PCT – Derwent

Requests	PCT	
42	45	Brazil
38	38	Patent applications in Brazil alone
4	7	Patent applications with PCT
6,337	7,248	Worldwide
5,484	5,484	Patent applications in the country of origin alone
853	1,764	Patent applications with PCT
6,379	7,293	Total

Source: Prepared by the study authors.

By analysing the data presented above, it is worth noting that the patent filing requests that multiply via PCT always have the same invention, changing only the number of countries in which it is filed. In this way,

removing the 42 patent applications filed in Brazil, we have 6,337 inventions with the IPC code C05F that are not filed in Brazil and that can be analysed, studied, and used in the country since they are not patented in its territory. By refining the prospecting to identify patent filing requests with the IPC code C05F, the types of applicants for patent filing requests were taken as parameters (individual – natural person; others – legal entity; university: higher education institutions and research centres) and the temporal evolution of filings, which followed a time frame between 2010 and 2023. Regarding patent filing applications – IPC C05F – in Brazil alone, there were 42 applications without PCT (Table 3) and 45 applications via PCT (Table 4). Among national filers, there was a predominance of individuals in filings with PCT (n=28; 66.6) or without PCT (n=31; 68.8%).

Table 3. Patent filing requests with WIPO IPC Green Inventory code C05F in Brazil alone – without PCT

Patent filing applications code C05F – Brazil – without PCT				
Year	Individual	Others	University	Total
1986				
2010	3	1		4
2011		1	1	2
2012	4	1		5
2013	1			1
2014				
2015	4		1	5
2016	3	1		4
2017	2	2		4
2018	2			2
2019	2			2
2020	1		1	2
2021	2	2		4
2022	3			3
2023	1	3		4
Total	28	11	3	42

Source: Prepared by the study authors.

Table 4. Patent filing requests with WIPO IPC Green Inventory code C05F in Brazil alone – with PCT

Patent filing applications C05F – Brazil – via PCT				
Year	Individual	Others	University	Total
1986				
2010	4	1		5
2011		1	1	2
2012	4	1		5
2013	1			1
2014				
2015	5		1	6
2016	3	1		4
2017	2	2		4
2018	2			2
2019	2			2
2020	1		1	2
2021	3	2		5
2022	3			3
2023	1	3		4
Total	31	11	3	45

Source: Prepared by the study authors.

When seeking to identify patent filing applications – IPC C05F – excluding Brazil, 6,337 patent applications without PCT (Table 5) and 7,278 applications via PCT (Table 6) were totalled. In addition, the temporal evolution of filings followed a time frame in 1986 and the period of 2010 and 2023. In this analysis, what stands out are

legal entity filers - others, both in filings with PCT (n=5,186; 71.55%) or without PCT (n=4,628; 73.03%), indicating business competition in the protection of their inventions worldwide.

Table 5. Patent filing requests with WIPO IPC Green Inventory code C05F excluding Brazil – without PCT

Patent filing applications code C05F excluding Brazil – without PCT				
Year	Individual	Others	University	Total
1986	1			1
2010	58	53	12	123
2011	57	83	20	160
2012	66	103	21	190
2013	97	202	36	335
2014	91	227	20	338
2015	153	362	35	550
2016	124	318	25	467
2017	106	320	29	455
2018	89	398	36	523
2019	89	419	46	554
2020	84	499	63	646
2021	110	651	44	805
2022	103	766	43	912
2023	38	227	13	278
Total	1,266	4,628	443	6,337

Source: Prepared by the study authors.

Table 6. Patent filing requests with WIPO IPC Green Inventory code C05F excluding Brazil – with PCT

Patent filing applications code C05F excluding Brazil – via PCT				
Year	Individual	Others	University	Total
1986	1			1
2010	79	80	17	176
2011	75	124	30	229
2012	86	153	36	275
2013	123	277	53	453
2014	115	315	33	463
2015	191	423	49	663
2016	133	354	33	520
2017	118	340	33	491
2018	103	434	39	576
2019	103	464	53	620
2020	97	528	72	697
2021	130	673	48	851
2022	112	791	49	952
2023	38	230	13	281
Total	1,504	5,186	558	7,248

Source: Prepared by the study authors.

Finally, when considering patent filing applications – IPC C05F – worldwide, 6,379 applications without PCT were identified (Table 7) and 7,293 applications via PCT (Table 8). Again, the analysis, taking the type of applicant as a reference, indicates that legal entities – others – are the main highlight in the number of patent filing requests, being identified in 71.26% (n=5,197) of requests with PCT and in 72.7% (n=4,639) of requests without PCT.

Table 7. Patent filing requests with WIPO IPC Green Inventory code C05F worldwide – without PCT

Patent filing applications C05F – worldwide – without PCT				
Year	Individual	Others	University	Total
1986	1			1
2010	61	54	12	127
2011	57	84	21	162
2012	70	104	21	195
2013	98	202	36	336
2014	91	227	20	338
2015	157	362	36	555
2016	127	319	25	471
2017	108	322	29	459
2018	91	398	36	525
2019	91	419	46	556
2020	85	499	64	648
2021	112	653	44	809
2022	106	766	43	915
2023	39	230	13	282
Total	1,294	4,639	446	6,379

Source: Prepared by the study authors.

Table 8. Patent filing requests with WIPO IPC Green Inventory code C05F worldwide – via PCT

Patent filing applications C05F – worldwide – via PCT				
Year	Individual	Others	University	Total
1986	1			1
2010	83	81	17	181
2011	75	125	31	231
2012	90	154	36	280
2013	124	277	53	454
2014	115	315	33	463
2015	196	423	50	669
2016	136	355	33	524
2017	120	342	33	495
2018	105	434	39	578
2019	105	464	53	622
2020	98	528	73	699
2021	133	675	48	856
2022	115	791	49	955
2023	39	233	13	285
Total	1,535	5,197	561	7,293

Source: Prepared by the study authors.

As a final refinement, this research focused on patent filing requests with code C05F from WIPO's IPC Green Inventory, taking into account data relating to the country of origin of patent application applicants and the temporal evolution of filings. Regarding countries of origin, all countries included in the Derwent database were considered. The temporal evolution of filings followed a period starting in 1986 and between 2010 and 2023.

Initially, applications for IPC C05F patent filings were analysed worldwide, without PCT, totalling 6,379 filings. In this context, and corroborating the global scenario of the main countries of origin for patent filings, China (CN) appears in the first place, with 5,756 (90.23%) applications, followed by the Russian Federation (UK), with 127 (1.99%) requests and by the Republic of Korea (KR), with 110 (1.72%) requests. Outside PCT, Brazil comes in fifth place, with 39 (0.61%) requests (Table 9).

Table 9. Patent filing requests with WIPO IPC Green Inventory code C05F according to country of origin – without PCT – Derwent

IPC C05F patent filing applications – Derwent –country of origin – without PCT																
Country	1986	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
CN		79	122	157	296	296	500	432	404	475	491	600	776	877	251	5,756
RU		7	12	9	6	9	14	8	14	9	8	15	4	7	5	127
KR		16	8	3	7	14	15	8	7	7	6	2	6	8	3	110
ID					2	4	1	3	4	16	6	3			1	40
BR		3	2	5	1		5	4	4	2	2	2	2	3	4	39
PH		3	3				4		6	1	5	11	2		2	37
TW		5	1	3	5	4	2	2	3	2	2	1	2	2	2	36
WO		3		3	1	3	3	1	3		2	1	6	2		28
VN			1	1	4	2	2	1	4	3			2	2	1	23
US		4	2	3	1	2		2		1	1	1	1	1		19
IN					1	1	1		3	2	3	1	1	1	1	15
DE		2	2		1	1			1	3		1		2	1	14
RO		2	1	2		1	2				3	1				12
JP	1			1	2		1	2	1			1		1	1	11
MX		1	1	3	2		1		1	1	1					11
PL			1	3	1		1	3	1			1				11
TR							1	1	1	1				1	6	11
AU			1			1						1	7			10
BY											8	2				10
ES		1	1		4		2		1	1						10
KZ											7			1		8
EP				1				1	1			1		3		7
FR		1			2						1			2	1	7
MY			1	1						1	1				1	5
EA											2				1	3
LU								1						2		3
AM											2					2
CA			1												1	2
GE											2					2
KG											2					2
MD												2				2
UZ											1	1				2
CZ			1													1
HU								1								1
NL			1													1
SG								1								1
HK																
NO																
ZA																
Total	1	127	162	195	336	338	555	471	459	525	556	648	809	915	282	6,379

Source: Prepared by the study authors.

When taking into account the same global scenario but taking as a refinement parameter in the search requests filed within the PCT scope, 7,293 documents were recovered. Of these, China (CN) maintains its position as the largest filing country for patent applications with 6,476 (88.79%), indicating that Chinese filers are also seeking patent protection in other countries. Next, the Russian Federation (RU), with 153 (2.09%), and the Republic of Korea (KR), with 143 (1.96%). Brazil comes in sixth place, with 45 (0.61) patent filing requests via PCT (Table 10).

Table 10. Patent filing requests with WIPO IPC Green Inventory code C05F according to country of origin – via PCT – Derwent

IPC C05F patent filing applications – Derwent –country of origin – via PCT																
Country	1986	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
CN		114	179	229	388	405	587	468	427	522	548	635	811	910	253	6,476
RU		8	16	12	9	14	21	9	15	9	8	15	4	7	6	153
KR		22	10	5	9	19	21	9	11	8	9	2	6	9	3	143
WO		3		4	7	3	5	5	3		4	6	6	3		49
TW		6	1	4	6	7	3	2	5	2	2	2	3	3	2	48
BR		5	2	5	1		6	4	4	2	2	2	5	3	4	45
ID				1	3	4	1	3	4	16	6	3			1	42
PH		3	3		1		4		6	1	5	11	2		2	38
US		5	3	4	1	3	3	5		1	1	1	2	1		30
VN			1	1	6	2	2	1	4	3		2	2	2	1	27
ES		4	2	1	8		4		1	2						22
EP				3				3	4	2		2	3	4		21
IN					2	1	1		4	4	4	1	1	1	1	20
RO		3	2	3		2	3				4	1				18
JP	1			1	4		2	3	2			1		1	1	16
DE		3	2		1	1			1	3		1		2	1	15
PL			2	3	2		1	4	1			2				15
AU			1			1	1					2	7	1		13
MX		2	1	3	2		1	1	1	1	1					13
TR							1	1	1	1	1	1		1	6	13
CA		1	2			1	2	1					2	1	1	11
BY											8	2				10
FR		2			2						2			2	1	9
KZ											7			1		8
MY			1	1	1					1	1				1	6
MD												4				4
NL			1					1	1			1				4
EA											2				1	3
LU								1						2		3
AM											2					2
CZ			2													2
GE											2					2
HU								2								2
KG											2					2
SG								1				1				2
UZ											1	1				2
ZA													1	1		2
HK					1											1
NO													1			1
Total	1	181	231	280	454	463	669	524	495	578	622	699	856	955	285	7,293

Source: Prepared by the study authors.

The data shows the current and growing patent scenario for fertilizers in Brazil and worldwide. It is noteworthy that the increase in the number of patent filing requests, with the fertilizer product, using code C05F of WIPO's IPC Green Inventory, in the period from 2010 to 2023, is due solely to filers originating in China, arriving to a total of 90.23% filings, as shown above in Table 15. China is the country of origin for the vast majority of patent application filings in the world in this survey, making it possible to verify a significant indicator of innovation performance in this country.

The main countries exporting the product to Brazil in 2023 were Russia, China and Canada, with Russia increasing its representation in volume compared to that recorded in the same period in 2022. In this sense, it is

important to mention the recent example of China. After years of increasing its domestic production and consumption of fertilizers, the country began to feel the environmental impacts caused by misuse. In 2015, China initiated a policy to reduce the growth in consumption of fertilizer molecules in the country, investing in precision agriculture (Farias, Oliveira, & Santos, 2023). Russia became the world's largest fertilizer exporter in the first half of the 2022-23 fiscal year, surpassing Canada, China, and the United States. The country has emerged as the world's largest fertilizer supplier, with US\$20.65 million in exports in the first half of the 2022-23 financial year, according to the latest report from the International Fertilizer Association (IFA). In second place is Canada, China in third, and the United States in fourth (Farias, Oliveira, & Santos, 2023).

Brazil currently remains the largest importer of fertilizers in the world. Around 80% of the fertilizers used in Brazilian agriculture come from abroad, according to a report from the National Association for the Diffusion of Fertilizers (Anda). The ability of national farmers to achieve a consistent and affordable supply of fertilizers directly affects crop yields, production, and food prices (Grandi, 2023).

Producing low-cost and sustainable fertilizers in countries heavily dependent on imports, such as Brazil, can be achieved by increasing the supply of domestically produced fertilizers in the market. Hence the importance of patents and the technological information contained in their documents (Castro, Silva, & Gilio, 2021; Salgado & Franchi, 2023). Patent applications for formulations such as fertilizers have grown significantly in Brazil over the last four decades. However, despite significant technological advances, not all patent applications are granted, which reinforces the incentive for new research and instruments that make inventions viable, as is the case with green patents (Farias et al., 2021; Lucas & Campos, 2023).

5. Conclusion

Patents have the same purpose, i.e., to offer an alternative product that increases and prolongs the active ingredient of the fertilizer and, therefore, reduces its applied quantity, contributing to sustainability and economic issues. The process of obtaining a patent carries a series of other data about the technology in question, such as the holders of rights to the invention, the institutions and inventors who developed it, the country where it was created and those countries where market exclusivity is sought for the invention. All this information is contained in patent documents which, in addition to technical data about the invention, are an important source of research and technological prospecting studies. The consolidation and analysis of patent documents allow the identification of technologies that can be exploited in the national territory, without the risk of violating patent rights; the identification of possible partners for licensing or joint development of technologies; updating on technological development in different sectors; the subsidy of research and development activities; the identification of new technologies emerging on the market; support investment decisions and seek technical solutions that exist in the state of the art.

In the case of fertilizers, as proposed by this study, patent prospecting demonstrated that there is a lot of technological information contained in patent documents, and such information could be used in Brazil, especially concerning environmentally friendly technologies, that is, green patents. The study also demonstrated that, although Brazil needs to increase the import of fertilizers every year, to date there is no research focused on this product. There is still little research on this essential product regarding Brazilian agribusiness and the environment.

On the other hand, patent prospecting demonstrated the exponential evolution worldwide of patent filing requests with code C05F of WIPO's IPC Green Inventory, reinforcing the pioneering stance of China, Russia, and South Korea, especially when compared to Brazil.

Finally, by seeking to identify patent filing requests filed around the world in the technological field of fertilizer products that have not been filed in Brazil and that can be explored by the national industry, the study demonstrates that there is a lot of technology at zero cost that can be used in the country about the fertilizer product taking into account the information contained in patent documents worldwide.

It should be noted that one of the biggest obstacles to the study is the volume of information contained in patent databases and the refinement stages of prospecting, which requires precision in the choice of terms and time frame. Future studies could focus on specific components of fertilizer formulations in order to broaden the range of new technologies applied to the product.

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Authors contributions

Mrs. Rosângela Aparecida da Silva Franchi is responsible for conceptualization, data collection, data analysis and interpretations. Prof. Dr. Eduardo Gomes Salgado responsible for data interpretations and review.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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